The 2005 *Dietary Guidelines for Americans* and risk of the metabolic syndrome[1–4]

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ABSTRACT

Background: The 2005 Dietary Guidelines for Americans Index (DGAI) was created to assess adherence to the dietary recommendations of the 2005 *Dietary Guidelines for Americans* (DGA) in relation to chronic disease risk.

Objective: The objective was to assess the relation between dietary patterns consistent with the 2005 DGA as measured by the DGAI and both the prevalence of the metabolic syndrome (MetS) and individual MetS risk factors.

Design: DGAI scores and metabolic risk factors for MetS were assessed in a cross-sectional study of 3177 participants from the Framingham Heart Study Offspring Cohort. MetS was defined on the basis of the National Cholesterol Education Program Adult Treatment Panel III criteria.

Results: After adjustment for potential confounders, the DGAI score was inversely related to waist circumference (P for trend $<$ 0.001), triacylglycerol concentration (P for trend $=$ 0.005), both diastolic (P for trend $=$ 0.002) and systolic (P for trend $=$ 0.01) blood pressure, the prevalence of abdominal adiposity (P for trend $<$ 0.001), and hyperglycemia (P for trend $=$ 0.03). The prevalence of MetS was significantly lower in individuals in the highest DGAI quintile category than in those in the lowest category (odds ratio: 0.64; 95% CI: 0.47, 0.88; P for trend $=$ 0.005) when those being treated for any of the risk factors were excluded. There was a significant interaction between DGAI score and age; the association between the DGAI score and MetS was confined largely to adults younger than 55 y (odds ratio: 0.57; 95% CI: 0.36, 0.92; P for trend $<$ 0.01).

Conclusions: A dietary pattern consistent with the 2005 DGA was associated with a lower prevalence of MetS—a potential risk factor for CVD. *Am J Clin Nutr* 2007;86:1193–201.

KEY WORDS Dietary pattern, metabolic syndrome, *Dietary Guidelines for Americans*, 2005 Dietary Guidelines for Americans Index

INTRODUCTION

Cardiovascular disease (CVD) ranks first as the cause of death among adult Americans (1). The metabolic syndrome (MetS) has been associated with an increased risk of CVD, by as much as 3-fold in some studies (2–5). MetS was defined in 2001 by the National Cholesterol Education Program Adult Treatment Panel III (ATP III) as the presence of ≥3 of the following risk factors: abdominal obesity (high waist circumference), hyperglycemia, hypertriacylglycerolemia, low HDL cholesterol, and hypertension (6). The criteria defining MetS were recently updated to lower the cutoff for hyperglycemia (fasting blood glucose: ≥100 mg/dL) and to include those undergoing treatment for some of the risk factors (7, 8). MetS is of particular concern because of its increasing prevalence. The prevalence of MetS based on the ATP III criteria increased from 28% in third National Health and Nutrition Examination and Survey (NHANES III, 1988–1994) to 32% in NHANES 1999–2000 (9, 10).

The US Departments of Agriculture and Health and Human Services issue dietary recommendations, the *Dietary Guidelines for Americans* (DGA), to help reduce the risk of CVD and other chronic diseases. The sixth version of the DGA, released early in 2005 (11, 12), is a departure from previous editions in that it emphasizes nutrient density, recommends a minimum amount of whole grain, recommends a limited intake of *trans* fats, recommends the intake of a greater variety of fruit and vegetables, and includes the new concept of "discretionary" calories.

Adherence to the 2000 DGA was previously recommended by the American Heart Association as a dietary approach to decrease risk and for the management of MetS (13). Updates and improvements to the 2005 DGA should theoretically improve the ability of such an eating pattern to decrease the risk of MetS. Some of the

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specific recommendations included in the 2005 DGA—an increased intake of whole grains and fruit and vegetables, a decreased intake of saturated fat, and the dietary pattern associated with the Dietary Approaches to Stop Hypertension (DASH)—appear to be associated with a decreased prevalence of MetS risk in some studies (14–19), but no study has yet examined the entire set of dietary recommendations included in the 2005 DGA to evaluate its effect on markers of CVD risk.

We developed the 2005 Dietary Guidelines for Americans Index (DGAI) to assess adherence to the 2005 DGA dietary recommendations (20), particularly in relation to chronic disease risk. This study evaluated the relation between dietary patterns consistent with the 2005 DGA, as measured by the DGAI, and both the prevalence of the MetS and individual risk factors for MetS, as defined by the ATP III.

SUBJECTS AND METHODS

Subjects

The original Framingham Heart Study began in 1948 as a longitudinal study to examine risk factors for heart disease among 5209 adults aged 28–62 y residing in Framingham, MA (21). The offspring of these participants and the offspring's spouses were invited to participate in the Framingham Heart Study Offspring Cohort; 5135 of the 6838 eligible individuals participated in the first examination (22). The fifth Framingham Offspring Cohort examination began in January 1991 and was completed in June 1995. A total of 3799 participants were examined. This study was approved by the Tufts–New England Medical Center Institutional Review Board for Human Studies.

Assessment of compliance with the 2005 *Dietary Guidelines for Americans*

Dietary intake was assessed with a semiquantitative food-frequency questionnaire (FFQ) (version1988-GP) developed by Willett et al (23, 24). The questionnaires were mailed to the participants before the examination, and the participants were asked to bring the completed FFQs with them to their appointments. The FFQ consisted of 126 items, including a list of foods with a standard serving size and a selection of 9 frequency categories ranging from never or <1 serving/mo to ≥ 6 servings/d. Participants were asked to report their frequency of consumption of each food item during the past year. Questions concerning the use of vitamin and mineral supplements, type of breakfast cereal most commonly consumed, and an open-ended question for foods commonly consumed but not listed on the FFQ were also included. Dietary information was judged as unreliable and excluded from further analysis if reported energy intakes were <2.51 MJ/d (600 kcal) or >16.74 MJ/d (4000 kcal/d) for women and >17.57 MJ/d (4200 kcal/d) for men or if ≥ 12 food items were left blank on the questionnaire. Participants who met the energy intake criteria and had <12 blank items were included in the analyses and were considered to be nonconsumers of the blank items.

The DGAI was developed to assess adherence to the key dietary intake recommendations of the 2005 DGA (11). Other recommendations that did not involve dietary recommendations for the general public, such as recommendations for special populations and activities unrelated to nutrients (eg, oral hygiene, physical activity, and food safety), were not included in the DGAI. Specifics concerning scoring of the DGAI are discussed at length elsewhere (20) and are summarized briefly below.

There were a total of 20 items on the DGAI. Eleven index items assessed the calorie-specific *food group intake* recommendations (based on 1 of the 10 adult calorie-specific patterns of the US Department of Agriculture food guide), and 9 were based on the *healthy choice* or *nutrient intake* recommendations (12). Each item had a maximum value of 1.0; most had a partial adherence score of 0.5, and 0 points were given when the recommendation was not achieved. Cutoff values for partial adherence were identified from intake distributions of the study population or nationally representative samples in a manner that helped to ensure sufficient variability in the scores of the individual items.

The *food group intake* recommendations were based on an appropriate calorie level for each participant; calorie levels were determined with the "estimated energy requirement" equation, which included height, weight, age, sex, and physical activity (25). Physical activity was determined by using the "walking equivalents method" described in the energy section of the Dietary Reference Intake (DRI) (25). The DGAI assessed food group intake with items for 5 vegetable subgroups (orange vegetables, dark-green vegetables, legumes, starchy vegetables, and other vegetables), variety of vegetables, fruit, grains, meat and legumes, milk and milk products, and discretionary calories. The latter is based on the consumption of sugars added to foods and beverages by individuals or during processing.

An important goal in the development of the DGAI was to limit the likelihood that an individual could receive a higher score solely by consuming more food, which was a major shortcoming of previous indexes (26). Thus, an important feature of the DGAI was a penalty of 0.5 points for exceeding the recommended intake of energy-dense foods. To determine which food groups to classify as energy dense, we analyzed the average energy contribution of a serving of each food group. Only the food items from each food group included in the FFQ were included in the determination of energy density. Energy-dense food groups were defined as those that, on average, had >50 calories per serving. Four food groups met the criteria: meat, milk and milk products, starchy vegetables, and grains.

Healthy choice recommendations were stated in absolute amounts of nutrient intake, or, for macronutrients, as a percentage of total kilocalories, and were independent of energy needs and were the same for all individuals (12). The DGAI items used to assess healthy choice recommendations were as follows: percentage of grains that are whole grain, fiber intake, sodium intake, alcohol consumption, and 5 recommendations related to fat and cholesterol intakes, including low-fat milk and meat choices, total fat and saturated as a percentage of calories, cholesterol intake, and *trans* fat intake.

Outcome measurement

The outcomes included the component risk factors used to diagnose MetS (waist circumference, fasting plasma glucose, triacylglycerol concentrations, HDL cholesterol, and systolic and diastolic blood pressure) in both their continuous form and as dichotomous variables based on their respective ATP III MetS cutoffs (**Table 1**).

Waist circumference was measured at the umbilicus while the participant was standing and with the tape measure parallel to floor. Fasting plasma glucose concentrations were measured in

TABLE 1
Prevalence of risk factors according to the National Cholesterol Education Program Adult Treatment Panel III (ATP III) criteria for the metabolic syndrome

Risk factors	ATP III criteria	Women[1] (n = 1684)	Men[1] (n = 1493)
		n (%)	n (%)
Metabolic syndrome[2]		511 (30)	639 (43)
Waist circumference	Men: ≥102 cm (≥40 in); women: ≥88 cm (≥35 in)	686 (41)	569 (38)
Fasting plasma glucose	≥100 mg/dL or drug treatment[3]	430 (26)	629 (42)
Triacylglycerols	≥150 mg/dL or drug treatment[4]	520 (31)	637 (43)
HDL cholesterol	Men: <40 mg/dL; women: < 50 mg/dL or drug treatment[4]	625 (37)	667 (45)
Elevated blood pressure	Systolic ≥130 mm Hg or diastolic ≥85 mm Hg or drug treatment[5]	709 (42)	826 (55)

[1] Individuals meeting the stated criteria.
[2] Defined as individuals meeting ≥3 of the listed criteria.
[3] Treatment of hyperglycemia defined as the use of oral antihyperglycemic agents or insulin.
[4] Treatment of elevated triacylglycerols or low HDL defined as the use of fibrates or nicotinic acid.
[5] Treatment defined as the use of antihypertensive agents.

fresh plasma with a hexokinase reagent kit (A-gene Glucose Test; Abbott, South Pasadena, CA). Glucose assays were run in duplicate. The intraassay CV for this method at the 5th examination cycle was <3% (27). Serum lipid profiles included the enzymatic measurement of total cholesterol and triacylglycerol concentrations and the measurement of the HDL cholesterol fraction after precipitation of LDL and VLDL cholesterol with dextran sulfate magnesium (28, 29). The intra- and interassay CVs were <3%. Blood pressure was measured twice with a mercury column sphygmomanometer and then averaged to the nearest 2 mm Hg. The use of hypoglycemic medication (insulin or oral agents), any antihyperlipidemic agents (including fibrates or nicotinic acid), and any antihypertensive agents was determined during the physical examination.

MetS was defined on the basis of the ATP III guidelines as the presence of ≥3 of the following risk factors: waist circumference ≥88 cm for women or ≥102 cm for men, fasting plasma glucose ≥100 mg/dL or drug treatment for hyperglycemia, HDL cholesterol <40 mg/dL for men and <50 mg/dL for women or drug treatment with fibrates or nicotinic acid, triacylglycerol ≥150 mg/dL or drug treatment with fibrates or nicotinic acid, or hypertension (systolic blood pressure ≥130 mm Hg or diastolic blood pressure ≥85 mm Hg or drug treatment for a previous diagnosis of hypertension) (6–8).

Covariates

Height (to the nearest 0.25 inch, or 0.6 cm) and weight (to the nearest 0.25 lb, or 113.5 g) were measured while the participants were standing with their shoes off and while wearing a hospital gown. Body mass index (BMI) was calculated as weight (in kg) divided by height (in m) squared (30, 31). Fasting insulin was measured in EDTA-treated plasma as total immunoreactive insulin (Coat-A-Count Insulin; Diagnostic Products Corporation, Los Angeles, CA) and run in duplicate. The intra- and interassay CVs ranged from 5% to 10%, and the lower limit of sensitivity was 8 pmol/L (27). Additional covariates included sex, age (in y), current smoker (yes or no), current multivitamin use (yes or no), current estrogen use (yes or no) in postmenopausal women only, total energy intake (kcal/d), and physical activity score assessed as a weighted sum of the proportion of a typical day spent sleeping and performing sedentary, slight, moderate, or heavy physical activities (expressed in metabolic equivalents) (32).

Statistical analyses

Of the 3799 members of the Framingham Offspring Cohort who participated in the 5th examination, complete dietary data were available for 3418. Individuals were excluded if they were missing information required to calculate their energy needs to determine a score on the DGAI, including height, weight, age, and physical activity score (n = 95), or if they were missing information needed to calculate MetS, either the levels of the biomarkers or medications used to treat abnormal levels of the components (n = 146). This reduced the final sample size to 3177 participants. Prevalence of the individual risk factors and MetS were calculated on the basis of ATP III criteria.

The DGAI scores were divided into approximate quintile categories (because the distribution of the scores did not allow for the determination of exact quintile values). Participant characteristics, adjusted for sex and age, were computed across quintile categories of DGAI score using the SAS PROC GLM procedure. The statistical significance for trend was assessed by using linear regression (SAS PROC REG) for continuous participant characteristics and logistic regression (SAS PROC LOGISTIC) for dichotomous characteristics; the DGAI score was entered as a continuous variable.

The dependent (outcome) variables included MetS as a dichotomous variable and the MetS components (waist circumference, fasting plasma glucose, triacylglycerols, HDL cholesterol, and systolic and diastolic blood pressure) as continuous and dichotomous variables based on the ATP III criteria.

For the assessment of the MetS component risk factors as continuous measures, those participants being treated for a given component were also excluded from the analyses (108 for fasting plasma glucose, 234 for the analysis of HDL and triacylglycerol, and 597 for the blood pressure analysis). All individual MetS components were positively skewed, and a natural logarithm transformation was applied to normalize the data. To express the transformed variables in their natural scale, geometric means were calculated by exponentiation of the adjusted least-squares means. Adjusted geometric means were computed across quintile categories of DGAI score by using the SAS PROC GLM procedure. The linearity assumption of the relation between the DGAI score and the MetS risk factors in their continuous form was examined by using the SAS LOESS procedure. The P value

for linear trend was determined as the *P* value for the DGAI linear regression coefficient with the DGAI score as a continuous variable using SAS PROC REG. First-order interactions were tested between DGAI score and age, sex, and BMI for each of the 6 MetS component risk factors. Because the number of interactions examined was large ($n = 18$), the level of significance for the interactions was adjusted to ≈0.003 by using a Bonferroni correction.

The odds ratios (ORs) relating DGAI score to risk of each of the individual risk factors for MetS were calculated by using SAS PROC LOGISTIC. The lowest DGAI score quintile category was designated as the reference category. The *P* value for trend was determined as the *P* value for the DGAI logistic regression coefficient with the DGAI score entered as a continuous variable. We used the revised ATP III criteria, which included specific treatments for some risk factors, as our primary definition of MetS and abnormal MetS risk factors. However, we also performed the analyses excluding those taking drugs for the treatment of hyperglycemia, low HDL concentrations, hypertriacylglycerolemia, or hypertension, as we did for the analysis of the risk factors in their continuous form. The latter analyses are discussed in the text only when there were differences between the analyses with and without individuals on the specified medications. Interactions were tested between DGAI score and age, sex, and BMI in separate models for each component risk factor by using the Bonferroni correction as describe above.

Potential confounding variables were examined in 4 successive stages for the analyses of the individual MetS components. Initial models were adjusted for age and sex (model 1). A second stage included adjustment for variables in the first model plus smoking, reported energy intake, estrogen use (women only), and physical activity (model 2). Next, the associations between the DGAI score and MetS components were mutually adjusted for the MetS components associated with DGAI score in model 2 (model 3). Because of the strong interrelations between systolic and diastolic blood pressure and between HDL-cholesterol and triacylglycerol concentrations, these were not mutually adjusted. Finally, BMI was added to the variables adjusted in model 3 (model 4). Because models 2–4 provided, in large part, very similar findings, only results from model 2 are presented in tabular form and differences between the models are discussed in the text.

The ORs relating DGAI score to risk of MetS were calculated by using SAS PROC LOGISTIC. The lowest DGAI score quintile category was designated as the reference category. The ORs were adjusted for age, sex, current smoking, current multivitamin supplement use, physical activity, and reported energy intake. The *P* for trend was determined as the *P* value for the DGAI logistic regression coefficient, with the DGAI score entered as a continuous variable. We used the revised ATP III criteria, which included specific treatments for some risk factors, as our primary definition of MetS. However, we also performed the analyses after excluding those taking drugs for hyperglycemia, low HDL concentrations, hypertriacylglycerolemia, and hypertension. Interactions were tested between DGAI score and age, sex, and BMI by using the Bonferroni correction. All statistical analyses were conducted by using SAS statistical software version 9.1 (SAS Institute, Cary, NC).

RESULTS

Our 3177 participants included 1493 men and 1684 women with a mean age of 54.5 y (range: 26–82 y). Forty-three percent of the men ($n = 639$), and 30% of the women ($n = 511$) met the ATP III criteria for MetS (Table 1). Of these, only 120 had a BMI < 25, whereas 1030 had a BMI ≥ 25. The prevalence of hypertension risk was the highest of the 5 risk factors for both men (55%) and women (42%). The mean (±SD) fasting insulin concentration in those with MetS was 40.4 ± 32.9 μU/mL (range: 14–720 μU/mL), whereas in those without MetS it was 26.1 ± 9.1 μU/mL (range: 11–180 μU/mL).

The DGAI score ranged from 3.0 to 18.0 out of possible 20 points. The total score was associated with many of the participant characteristics (**Table 2**). Those in the highest DGAI score quintile category were significantly more likely to be women than men (73% compared with 30%; $P < 0.001$) and were significantly older (57 compared with 52 y; $P < 0.001$) than those in the lowest quintile category. After adjustment for age and sex, those in the highest DGAI quintile category were significantly more likely than those in the lowest quintile category to use multivitamin supplements (39% compared with 23%; $P < 0.001$), had a lower average BMI (26.6 compared with 28.2; $P < 0.001$), were significantly less likely to be current smokers (8% compared with 35%; $P < 0.001$), and were more likely to be taking medication for one or more MetS components (28% compared with 21%; $P < 0.001$). There was no significant difference in fasting plasma insulin, total reported energy intake, or physical activity between the highest and lowest quintile categories.

Five of the MetS components, in their continuous form, were inversely associated with DGAI score after adjustment for age and sex: waist circumference (*P* for trend < 0.001), fasting plasma glucose (*P* for trend $= 0.03$), plasma triacylglycerol (*P* for trend $= 0.002$), and systolic (*P* for trend $= 0.02$) and diastolic (*P* for trend $= 0.03$) blood pressure. Further adjustment for smoking, energy intake, estrogen use (women only), total energy intake, and physical activity did not have a substantial effect on these associations, but the fasting plasma glucose association with DGAI score was slightly attenuated and was no longer statistically significant (*P* for trend $= 0.06$) (**Table 3**). After mutual adjustment among the risk factors that remained associated with the DGAI score (waist circumference, plasma triacylglycerol, and blood pressure), only waist circumference remained independently associated with DGAI score.

We considered possible interactions, based on a priori decisions, between DGAI score and age, sex, and BMI for each of the MetS components in their continuous form in separate models. Only the interaction between systolic blood pressure and age ($P = 0.002$) met our criteria for statistical significance ($P < 0.003$). When the population was stratified, the relation was confined to those younger than 55 y ($P = 0.009$) and was not significant in those who were older ($P = 0.69$).

When the MetS risk factors were considered as dichotomous variables based on the revised ATP III definitions, those in the highest DGAI score category had a significantly lower risk of abdominal adiposity (OR: 0.50; 95% CI: 0.39, 0.64; *P* for trend < 0.001) and of hyperglycemia (OR: 0.73; 95% CI: 0.56, 0.94; *P* for trend $= 0.03$) than did those in the lowest DGAI category after adjustment for age, sex, current smoking status, current multivitamin use, physical activity, and reported energy intake (**Table 4**). The relation with hyperglycemia risk became somewhat stronger when those receiving treatment for this condition were excluded (OR: 0.67; 95% CI: 0.51, 0.88; $P < 0.005$).

TABLE 2
Participant characteristics according to quintile category of the 2005 Dietary Guidelines for Americans Index (DGAI)[1]

	2005 DGAI quintile category					*P* for trend[2]
	1	2	3	4	5	
Median DGAI score[3]	6.75 (3.0–8.0)	9.25 (8.25–10.0)	11.00 (10.25–11.5)	12.50 (11.75–13.0)	14.25 (13.25–18.0)	
Participants (*n*)	656	614	657	601	649	
Median healthy choice subscore[4]	3.5	4.0	5.0	5.75	7.0	
Median food group subscore[5]	3.0	5.0	6.0	6.5	7.5	
Female (%)[6]	30 (26, 33)	45 (41, 48)	55 (52, 60)	63 (59, 67)	73 (69, 77)	< 0.001
Age (y)[6]	51.8 (51.0, 52.5)	53.4 (52.6, 54.2)	54.5 (53.7, 55.2)	55.7 (54.9, 56.5)	57.1 (56.3, 57.8)	< 0.001
BMI (kg/m^2)[7]	28.2 (27.8, 28.5)	27.5 (27.0, 27.8)	27.3 (26.9, 27.7)	27.3 (26.8, 27.6)	26.6 (26.0, 26.8)	< 0.001
Fasting plasma insulin (μU/mL)[7,8]	32.9 (31.1, 34.6)	30.4 (28.6, 32.2)	32.4 (30.7, 34.1)	30.3 (28.4, 32.0)	30.2 (28.4, 32.0)	0.08
Total reported energy (kcal/d)[7]	1806 (1750, 1847)	1898 (1849, 1946)	1937 (1887, 1991)	1870 (1829, 1928)	1844 (1787, 1894)	0.51
Physical activity score (METS)[7]	35.0 (34.4, 35.4)	34.8 (34.3, 35.3)	34.4 (33.9, 35.0)	34.6 (34.2, 35.2)	34.9 (34.5, 35.4)	0.37
Current smokers (%)[6]	35 (32, 38)	21 (18, 24)	20 (17, 23)	10 (7, 13)	8 (5, 11)	< 0.001
Multivitamin users (%)[6]	23 (20, 27)	24 (21, 28)	27 (23, 30)	31 (27, 35)	39 (35, 42)	< 0.001
Metabolic syndrome treatment (%)[6,9]	21 (18, 24)	23 (20, 26)	24 (21, 27)	26 (23, 30)	28 (25, 31)	< 0.001

[1] Means and percentage adjusted for sex and age. Age adjusted for sex only and sex for age only. METS, metabolic equivalents.
[2] Derived from linear regression for continuous variables or logistic regression for dichotomous variables.
[3] Range in parentheses. Scores range from 0 to 20 possible points.
[4] Scores range from 0 to 9 possible points and are assessed at the same level for all participants. The 9 items used to assess the healthy choice recommendations are as follows: percentage of grains that are whole grain, fiber intake, sodium intake, alcohol consumption, low-fat milk and meat choices, total and saturated fat as a percentage of calories, cholesterol intake, and *trans* fat intake.
[5] Scores range from 0 to 11 possible points and are assessed on a calorie-specific level. The 11 items used to assess the food group recommendations are as follows: orange vegetables, dark-green vegetables, legumes, starchy vegetables, other vegetables, vegetable variety, fruit, grains, meat and legumes, milk and milk products, and discretionary calories (added sugar).
[6] Values are arithmetic $\bar{x}$; 95% CIs in parentheses.
[7] Values are geometric $\bar{x}$; 95% CIs in parentheses.
[8] $n = 3073$.
[9] Medication for one or more MetS components.

We tested the interaction between the presence of the ATP III–defined MetS risk factors and age, sex, and BMI in separate models. The interaction between BMI and elevated waist circumference ($P < 0.001$) and age and hypertension risk ($P < 0.001$) met our criteria for statistical significance. When stratified by BMI, there was an inverse association between the prevalence of abdominal adiposity and DGAI score for individuals with a BMI ≥ 25 (OR: 0.57; 95% CI: 0.42, 0.78; *P* for trend < 0.001 for the comparison of the prevalence in the highest and the lowest DGAI quintile category), but not for those with a BMI < 25 (OR: 0.84; 95% CI: 0.34, 2.07; *P* for trend = 0.75). After stratification into those aged ≥55 y and those aged <55 y, the association between hypertension and DGAI score was not statistically significant in either age strata.

We also observed an inverse association between adherence to the DGA and risk of MetS after multivariable adjustment (**Table 5**). The OR for the comparison of the prevalence of MetS among individuals in the highest DGAI score quintile category

TABLE 3
Geometric means (and 95% CIs) for each of the component risk factors for the metabolic syndrome according to quintile category of the 2005 Dietary Guidelines for Americans Index (DGAI)[1]

	2005 DGAI quintile category					*P* for trend[2]
	1	2	3	4	5	
DGAI range	<8.25	8.25–10.00	10.25–11.50	11.75–13.00	>13.00	
Participants ($n = 3177$)	656	614	657	601	649	
Component risk factors						
Waist circumference (cm)	94 (93, 95)	92 (91, 93)	91 (90, 92)	91 (90, 92)	89 (88, 90)	< 0.001
Glucose (mg/dL)[3]	97 (96, 98)	97 (96, 98)	97 (96, 98)	97 (96, 98)	95 (94, 96)	0.06
Triacylglycerols (mg/dL)[4]	128 (120, 131)	121 (116, 125)	122 (118, 127)	121 (116, 126)	115 (111, 120)	0.005
HDL cholesterol (mg/dL)[4]	49 (47, 50)	49 (48, 50)	48 (47, 49)	48 (47, 49)	49 (47, 50)	0.58
Systolic blood pressure (mm Hg)[5]	123 (122, 125)	122 (121, 123)	123 (121, 124)	121 (120, 122)	122 (121, 124)	0.01
Diastolic blood pressure (mm Hg)[5]	75 (74, 75)	73 (72, 74)	74 (73, 74)	73 (72, 74)	73 (72, 74)	0.002

[1] Means adjusted for sex, age, energy intake, smoking status, estrogen use (women only), multivitamin use, and physical activity.
[2] Based on the linear regression coefficient for the DGAI score as a continuous variable.
[3] Based on 3069 participants; 108 participants were excluded from these analyses because they were treated with oral hypoglycemic agents or insulin.
[4] Based on 2943 participants; 234 participants were excluded from these analyses because they were treated with lipid-lowering medication.
[5] Based on 2580 participants; 597 participants were excluded from these analyses because they were treated with antihypertensive medication.

TABLE 4
Odds ratios for each component of the metabolic syndrome according to quintile category of the 2005 Dietary Guidelines for Americans Index (DGAI)

	2005 DGAI quintile category					
	1	2	3	4	5	*P* for trend[1]
DGAI range	<8.25	8.25–10.00	10.25–11.50	11.75–13.00	>13.00	
Participants (*n*)	656	614	657	601	649	
Mean no. of component risk factors	2.11	1.95	2.00	1.99	1.86	
Component risk factors[2]						
Waist circumference risk						
Odds ratio (95% CI)[3]	1[4]	0.70 (0.55, 0.87)	0.64 (0.51, 0.81)	0.59 (0.47, 0.75)	0.50 (0.39, 0.64)	< 0.001
n[5]	300	242	257	228	228	
Hyperglycemia						
Odds ratio (95% CI)	1	0.92 (0.72, 1.18)	0.93 (0.73, 1.19)	1.1 (0.83, 1.37)	0.73 (0.56, 0.94)	0.03
n[5]	236	206	219	216	182	
Hypertriacylglycerolemia						
Odds ratio (95% CI)	1	0.98 (0.77, 1.23)	0.96 (0.75, 1.21)	0.99 (0.78, 1.27)	0.91 (0.71, 1.17)	0.42
n[5]	251	225	238	219	224	
HDL risk						
Odds ratio (95% CI)	1	0.97 (0.77, 1.22)	1.17 (0.93, 1.47)	1.09 (0.86, 1.39)	1.11 (0.87, 1.42)	0.16
n[5]	278	240	282	238	254	
Hypertension						
Odds ratio (95% CI)	1	0.86 (0.67, 1.09)	0.90 (0.71, 1.15)	0.87 (0.68, 1.12)	0.87 (0.68, 1.12)	0.32
n[5]	319	286	318	292	320	

[1] Based on the logistic regression coefficient for the DGAI score as a continuous variable.
[2] Based on National Cholesterol Education Program Adult Treatment Panel III (ATP III) criteria (*see* Table 1).
[3] Adjusted for age, sex, energy intake, physical activity, multivitamin use, and smoking status.
[4] Reference category.
[5] Number of participants with a component risk factor based on ATP III criteria.

and the lowest category was marginally significant (OR: 0.81; 95% CI: 0.63, 1.04; *P* for trend = 0.07). When those receiving treatment for any of the risk factors were excluded, this comparison became statistically significant (OR: 0.64; 95% CI: 0.47, 0.88; *P* for trend = 0.005). There was also a marginally significant interaction between the DGAI score and age for MetS after Bonferroni correction (*P* = 0.02). When we stratified the participants into those age ≥55 y and those aged <55 y, we observed no association between MetS and DGAI score in the older individuals (*P* for trend = 0.89). However, there was a strong inverse association among the younger participants, with an OR equal to 0.61 (95% CI: 0.41, 0.91; *P* for trend = 0.007) for the comparison of those in the highest and lowest quintile categories of DGAI score. This relation was not affected when those receiving treatment for any of the risk factors were excluded (OR: 0.57; 95% CI: 0.36, 0.92; *P* for trend = 0.007). We considered the possibility that the lack of any association in older individuals was a consequence of greater medical treatment for abnormal component risk factors for MetS, but the relation between DGAI and MetS in those aged ≥55 y was still not statistically significant when those receiving treatment for any of the risk factors were excluded (*P* for trend = 0.32).

DISCUSSION

We found that consumption of a diet consistent with the 2005 DGA dietary recommendations is associated with both lower levels of many of the risk factors of MetS and a reduced prevalence of MetS. Given the greatly enhanced CVD risk among individuals with MetS, this study provides the first evidence that adherence to the 2005 DGA is associated with a risk factor profile predisposing to reduced CVD risk.

The Healthy Eating Index (HEI) was developed by US Department of Agriculture scientists to assess adherence to the 1990 version of the DGA (26). The relation between the HEI and CVD outcomes was studied in 2 longitudinal studies (33, 34). In men, the HEI was associated with a 28% (relative risk = 0.72; 95% CI: 0.60, 0.88; *P* < 0.001) lower risk of CVD outcomes (33); in women, there was a 14% (relative risk = 0.86; 95% CI: 0.72, 1.03) reduction in CVD risk, which was not statistically significant (34). These studies indicate that adherence to the 1990 DGA as assessed by the HEI might modestly influence CVD risk.

Recent studies have examined the relation between HEI score and another proposed intermediate risk factor for CVD, chronic low-grade inflammation, indicated as an elevated C-reactive protein (CRP). Fung et al (35), in the same population studied above, failed to see an association between HEI scores and elevated CRP in women. On the other hand, Ford et al (36) showed a modest inverse relation between HEI score and elevated CRP (defined as CRP ≥ 85th percentile) in NHANES III, but the association appeared to be confined to women (OR: 0.57; 95% CI: 0.41, 0.79; *P* for trend < 0.01) and was not statistically significant in men (OR: 0.98; 95% CI: 0.69, 1.39), which is contrary to the results seen for the relation between HEI and CVD outcomes (33, 34). In our population, we observed no significant interaction between sex and DGAI score for MetS or any of the individual risk factors. However, we previously reported a significant sex interaction between DGAI score and degree of insulin resistance as assessed by the homeostasis model assessment of insulin resistance (37).

TABLE 5
Odds ratios for the metabolic syndrome according to quintile category of the 2005 Dietary Guidelines for Americans Index (DGAI) and age[1]

	2005 DGAI quintile category					
	1	2	3	4	5	*P* for trend[2]
DGAI range	<8.25	8.25–10.00	10.25–11.50	11.75–13.00	>13.00	
All participants (*n*)	656	614	657	601	649	
Metabolic syndrome (*n*)	255	221	238	217	219	
Odds ratio (95% CI)[3]	1[4]	0.89 (0.70, 1.13)	0.89 (0.70, 1.13)	0.89 (0.70, 1.15)	0.81 (0.63, 1.04)	0.07
All participants except those excluded because of treatment[5]	538	490	515	453	480	
Metabolic syndrome (*n*)	171	124	140	118	102	
Odds ratio (95% CI)	1	0.75 (0.57, 1.00)[2]	0.83 (0.63, 1.10)	0.82 (0.61, 1.11)	0.64 (0.47, 0.88)	0.005
Age <55 y (*n*)[6]	400	332	338	274	267	
Metabolic syndrome (*n*)	140	82	86	66	54	
Odds ratio (95% CI)	1	0.67 (0.48, 0.94)	0.73 (0.52, 1.03)	0.70 (0.49, 1.02)	0.61 (0.41, 0.91)	0.007
Age ≥55 y (*n*)	256	282	319	327	382	
Metabolic syndrome (*n*)	115	139	152	151	165	
Odds ratio (95% CI)	1	1.27 (0.89, 1.79)	1.19 (0.84, 1.67)	1.19 (0.84, 1.67)	1.09 (0.77, 1.54)	0.89

[1] Diagnosis of metabolic syndrome based on the National Cholesterol Education Program Adult Treatment Panel III (ATP III) criteria (*see* Table 1).
[2] Based on the logistic regression coefficient for the DGAI score as a continuous variable.
[3] Adjusted for age, sex, energy intake, physical activity, multivitamin use, and smoking status.
[4] Reference category.
[5] Calculations exclude all those who were treated for hyperglycemia, hypertension, hypertriglyceridemia, or low HDL ($n = 2476$; $n = 655$ for those with metabolic syndrome).
[6] *P* value for interaction with age = 0.02.

Our findings suggest that the association between MetS and consumption of a diet consistent with the 2005 DGA as assessed by the DGAI is due largely to 4 of its 5 component risk factors: waist circumference, fasting plasma glucose, plasma triacylglycerol, and blood pressure (hypertension). However, the associations between the DGAI and these metabolic markers may not be completely independent. For example, after mutual adjustment, only waist circumference remained significantly associated with DGAI score. The importance of diet quality in determining weight was previously shown in the Framingham Offspring Cohort (38). A better diet quality based on a 5-point index derived from two 3-d diet records was associated with less weight gain over an 8-y period.

Previous studies have shown inverse associations between whole grain intake and waist circumference, fasting plasma glucose, and plasma triacylglycerol in the Framingham Offspring Cohort (14, 15). Other recommendations in the DGA, including sodium restriction and increased fruit and vegetable intake, consistent with the DASH diet, are also associated with lowered blood pressure and risk of hypertension (39, 40). Therefore, increased intakes of whole grains, fruit, and vegetables and other recommendations included in the 2005 DGA could be biologically plausible mediators of the association we observed with these metabolic risk factors.

HDL-cholesterol concentration was not related to the index score as a continuous measure or as a dichotomous measure. HDL cholesterol is affected by weight and physical activity (41, 42), and many dietary factors included in the DGA key recommendations (43). The failure to see an association between the index and HDL cholesterol may be due to 2 factors. First, the DGA key recommendation for alcohol intake, which was previously shown to be a strong determinant of HDL cholesterol in the Framingham Offspring Cohort (44), is coded within the index in a manner that may minimize any association with HDL-cholesterol concentrations. That is, individuals who consumed no alcohol were classified as meeting the recommendation and women consuming >1 drink/d and men consuming >2 drinks/d were classified as not meeting the recommendation. Second, adherence to some of the key dietary recommendations, such as the fat recommendations, may have a negative effect on HDL-cholesterol concentrations but an overall beneficial effect on the total to HDL cholesterol ratio, which is not a component of MetS.

We should also note that the observed significant differences in the MetS component risk factors between the extreme quintile categories of the DGAI score were modest and may not be clinically significant at the individual level. However, such differences may prove more important at the population level. Moreover, these differences in component risk factors translate into much more notable differences across quintile categories of the DGAI for MetS.

These findings are subject to some potential limitations. Because this study was cross-sectional, it is impossible to know whether some participants altered their diet or altered their reporting of diet in some way based on previous diagnoses related to risk of MetS. Also, those who were aged >55 y and did not have MetS may have followed a diet consistent with the 2005 DGA earlier in life, which may contribute to their current good health. Furthermore, the large number of people older than 55 y with MetS who are being treated for hypertension and other risk factors may also limit the study's findings, because it is possible that diet would not affect risk factor levels to the same degree among individuals receiving treatment. However, a recent report from the Health Professionals Follow-Up Study suggests that men taking medication for hypertension or hypercholesterolemia would benefit from lifestyle changes, including improved diet quality (45). Moreover, when we excluded participants taking

drugs for the individual risk factors from the analyses, we observed similar relations.

This DGAI was designed to assess only the dietary intake portion of the 2005 DGA. We did not include the recommendations to "control calorie intake to manage body weight" and "be physically active every day" in the index, although they are important recommendations with strong influences on MetS and insulin resistance. An earlier index of adherence to the DGA showed that these nondietary factors overpowered dietary relations with chronic disease (46). We chose to control for these factors in our analysis so that we could examine the relation between the dietary composition and intermediate CVD risk factors. This may be another reason why we were unable to see a relation between the DGAI score and HDL-cholesterol concentration because it seems to be primarily related to exercise and body weight (41, 42).

Another potential limitation of this work was the use of an FFQ for dietary assessment; however, much evidence from the literature supports the validity of the Harvard FFQ for assessing food and nutrient intakes. Median correlation coefficients between food group intake based on two 1-wk diet records and an FFQ covering the same time period were 0.46 for vegetables, 55 for grains, 0.70 for meat and fish, 0.71 for dairy, 0.77 for fruit, and 0.84 for alcoholic beverages (47). The energy-adjusted correlation coefficients between dietary intakes from the diet records and FFQ were 0.60 for sodium, 0.67 for total fat, 0.68 for dietary fiber, 0.75 for saturated fat, and 0.78 for cholesterol (24). These reports showed the relative validity of the information from the Harvard FFQ used to determine intake of the food group and healthy choice index items.

Finally, we do not know whether our population was representative of all adult Americans, but the prevalence of MetS in the Framingham Offspring Cohort was similar to that for adult Americans (9, 48). However, it is important to note that this cohort is almost exclusively white.

To our knowledge, this was the first study to assess a diet consistent with the 2005 DGA and prevalence of MetS and its metabolic risk factors. This research provides evidence that the 2005 DGA recommendations present a healthy eating pattern associated with a reduced chronic disease risk profile in a community-based US adult population. Future studies, including dietary intervention studies, will be needed to confirm the effects of the 2005 DGA dietary patterns on other intermediate markers of disease and on the prevention of new cases of disease.

The authors' responsibilities were as follows—JJF-C: designed the index, conducted the analysis, and drafted the manuscript; LMT: assisted in the development of the index; and ES, JTD, MLM, LMT, and PFJ: assisted in the creation and design of the project. All authors participated in the revision and approval of the manuscript. JBM was supported by an American Diabetes Association Career Development Award; received research grants from GlaxoSmithKline, Wyeth and Sanofi-Aventis; and served on safety or advisory boards for GlaxoSmithKline, Merck, and Lilly. None of the other authors had a potential conflict of interest.

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